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# Winter Injury of Sagebrush and Other Wildland Shrubs in the Western United States

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## RESEARCH SUMMARY

Extensive winter injury of native wildland shrubs occurred in the Western United States during the winter of 1976-77. *Artemisia tridentata* was damaged most extensively followed by *Ceanothus* spp., *Arctostaphylos* spp., *Purshia* spp., and 32 other species of shrubs. The record low precipitation during this period, and consequential low snow cover in areas of normally heavy snow cover, combined with other factors that led to the injury.

*Cover Photo—A mountain valley at the headwaters of the Big Lost River on the Challis National Forest in south-central Idaho. Virtually all mountain big sagebrush plants were killed.*

# Winter Injury of Sagebrush and Other Wildland Shrubs in the Western United States

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## INTRODUCTION

Wildland shrubs are increasingly important on western rangelands (McKell and others 1972; McKell 1975a, 1975b; McArthur and others 1974) in the restoration of disturbed areas (McArthur and others 1974; Monsen 1975) and for use on big-game ranges (Plummer and others 1968). Sagebrush, *Artemisia* spp., alone occurs on more than one-third of the 820 million acres (332 million ha) of western shrublands (Beetle 1960; Plummer 1974). Its importance stems, if not from its ubiquity, from its aggressiveness and tremendous diversity and adaptability (Beetle 1960; McArthur and Plummer 1978).

Weather extremes are a recognized important environmental element in the survival and natural selection of plants. The low precipitation period during the winter of 1976–77 may have been an example of such an extreme. Precipitation during this period was near the lowest in recorded history over most of the West. Following that winter, extensive areas of sagebrush kill were observed in Idaho, Nevada, Utah, western Wyoming, and western Colorado. Severe damage to other shrub species was also observed. Winter injury appeared to be the primary cause. Some plant species appear to have been killed or damaged by drought alone.

The objective of this paper is to briefly review winter injury of plants and shrubs in particular, document the observed winter injury of 1976–77, and correlate the occurrence with weather records.

## REVIEW

Winter injury of conifers, hardwood trees, and ornamental shrubs is well documented (for example, Hubert 1918; Hilborn 1937; Nash 1943; Hunter-Blair 1946; Spaulding 1946; Wisconsin Department of Agriculture 1948; Curry and Church 1952; Duffield 1956; Daubenmire 1957; Day and Peace 1946; Powell 1972). However, reference to winter injury of endemic wildland shrubs is relatively rare. Cottam (1937) reported extensive damage to *Covillea tridentata* (*Larrea divaricata* Cav., creosote bush), *Strombocarpa ordata* (*Prosopis pubescens* Benth., mesquite), and *Prosopis glandulosa* (*Prosopis juliflora* [SW.] DC) following a cold period in southwestern Utah. In this instance the damage was probably caused by freezing of plant tissue, and most of the plants apparently recovered (Frosberg 1938). Frost injury of bitterbrush (*Purshia tridentata*) occurred over a large area of eastern California when several unusually cold, below freezing days followed an unusual warm spell in early April that stimulated bud growth (Smith and others 1965). Exposed bitterbrush foliage was damaged in northern Utah apparently from extreme temperatures of -35°F (-37°C) and -37°F (-38°C) in early December and January following relatively warm periods (Jensen and Urness 1979). Fourwing saltbush (*Atriplex canescens*) received winter injury in two off-site performance plantings in central Utah (Van Epps 1975). The injury in this case was attributed primarily to unusually low temperatures; hardiness varied with the point of origin of the 20 accessions. Schumaker and others (1979) and Hanson and others (1982) reported the loss of *Artemisia tridentata* ssp. *vaseyana* (mountain big sagebrush) in an area of southwestern Idaho that occurred during winter 1976–77. Areas of most intense kill were those normally covered by 3.3 ft (1 m) or more of snow. They hypothesized that sagebrush plants remained active during most of the winter and became desiccated due to lack of normal soil moisture. A 50 percent loss of shrub cover and increase in grass and forbs followed the sagebrush kill. Buckbrush (*Ceanothus* sp.) (Stickney 1965) and manzanita (*Arctostaphylos* spp.) commonly incur winter injury throughout the West during winters of incomplete snow cover. Perhaps due to the commonness of this injury and usual recovery little attention is given. Tarry and Shaw (1966) associated *Armillaria mellea*, a root pathogen, with a dieback disease of *Ceanothus* spp. following winter injury in the Pacific Northwest.

Winter injury has a rather broad meaning, and the mechanism is not completely understood (Slatyer 1976). Plants presumably suffer winter injury by freezing due to a lack of sufficient innate cold hardiness or absence of winter dormancy in cold-hardy plants, and due to winter drought or desiccation (Michael 1963, 1967; Tranquillini 1964; Kramer 1969; Mazur 1969; Sakai 1970; Alden and Hermann 1971). Winter injury to nonindigenous or exotic plants adapted to warmer regions can usually be attributed to direct freezing. Plants in their native habitat or exotics may suffer damage from absence of winter dormancy or from desiccation, and the critical periods are usually in early and late winter (Day and Peace 1946; Peace 1962; Parker 1963).

Dormancy is an adaptive phenomenon in plants that enables them to resist and survive moisture and temperature extremes of the external environment where they are indigenous. External environmental factors that initiate dormancy by influencing growth are usually a combination of temperature, moisture, nutrition, light quality, photoperiod, and temperature during light and dark periods (Vegis 1964). The characteristic response

of plant species to these factors in the initiation and length of dormancy is hereditarily controlled. Prior to dormancy or full rest formation in fall or early winter, an unusual cold wave can result in freezing injury to native as well as exotic plants. In late winter after dormancy has ended, an unusual warm spell that stimulates growth activity, followed with a return to winter cold, can result in freezing injury. Leaf and shoot kill of evergreen plants during winter and spring is usually expressed later during the summer as the foliage turns brown (for example, Felt 1943). The other type of winter injury, desiccation, is thought to result from lethal dehydration resulting from continued transpiration with lack of sufficient water absorption from the root system (Kramer 1969). With the absence of snow cover, the soil and root systems may freeze; or with severe cold, lower stems may freeze, preventing replacement of transpirational water loss in upper plant parts (Olberg 1955; Sakai 1970). Rapid temperature fluctuations, drying winds, and bright sunny winter or early spring days are believed to be related to this type of winter injury (White and Weiser 1964; Watanabe 1969).

## METHODS

Extensive kill of sagebrush was called to our attention by Walt Mueggler and Ed Schlatterer of the USDA Forest Service, and G. A. Schumaker, USDA Science and Education Administration, Boise, Idaho. They observed areas of recently killed plants in central and southern Idaho during summer 1977. We visited these areas and others in Utah during September 1977 in an attempt to determine the cause. The extensive nature and pattern of damage, not only to sagebrush but also to other shrub species, implicated winter injury as the probable cause. In view of the extraordinarily low precipitation during winter 1976–77 throughout most of the West, it seemed worthwhile to determine the extent of winter injury to sagebrush and other shrub species throughout the West. To accomplish this, it seemed expedient to make a survey of land management units of the Forest Service, Bureau of Land Management, and State Divisions of Wildlife Resources. Because our primary interest was big sagebrush (*Artemisia tridentata*), we limited the survey to the general distributional limits of this species (Little 1976), excluding Washington, Arizona, New Mexico, and southern California (fig. 1). Information requested included (1) shrub species affected, (2) location, (3) elevation, (4) intensity of injury, and (5) symptoms observed.

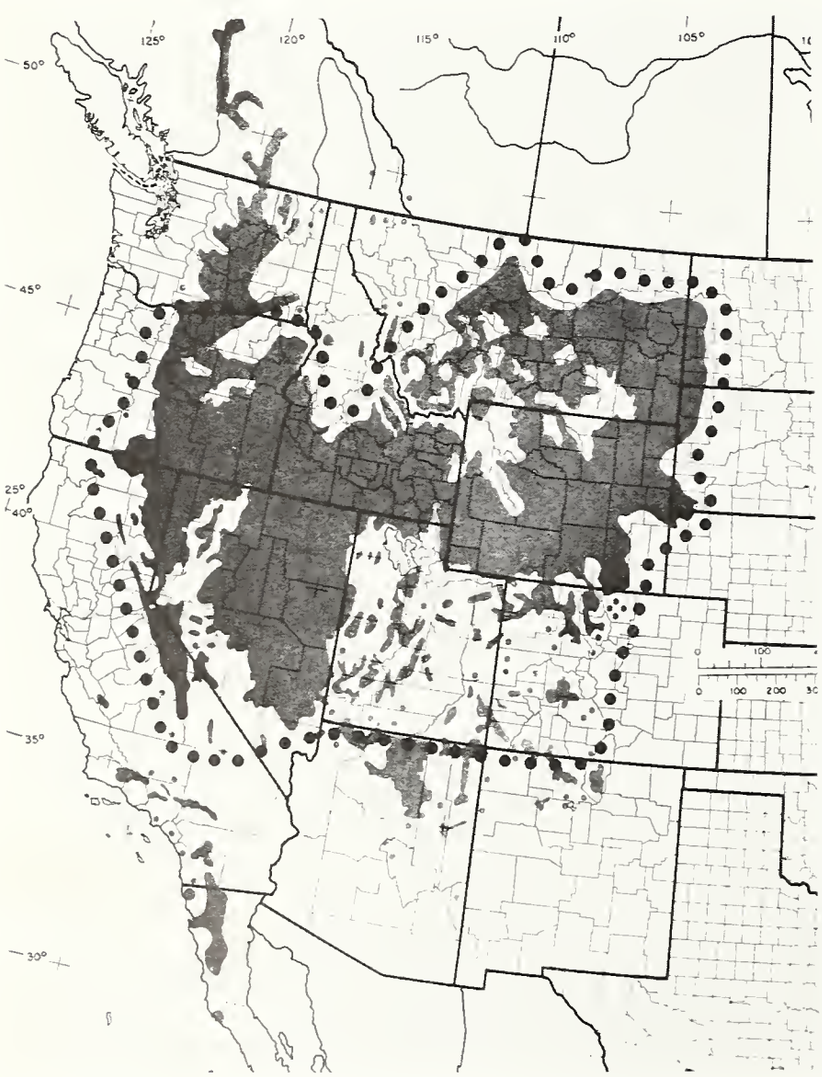


**Figure 1.—Distribution of *Artemisia tridentata* in the western United States. Dotted line encircles the general limits of the winter injury survey.**

Climatological data for the States falling within the area of interest were obtained from the National Oceanic and Atmospheric Administration, National Climatic Center, Ashville, N.C. Monthly precipitation and temperature records were examined for October through April 1976–77. The monthly actual and percentage of normal climatic divisional average precipitation was computed for each State. Only those divisions that fell within the survey limits were used to obtain the average for each State. The average monthly means and degrees (°Farenheit) temperature departures from normal were computed for each State for the same climatic division as for precipitation. Precipitation and temperature normals were based on the 1941–70 record. Precipitation in areas of little or no reported winter injury was compared with that of those where the most extensive injury was reported. This was done by matching management areas with climatic divisions and selecting those that corresponded most closely. Other factors considered were elevation (that is, mountains, valleys, plateaus) and distribution of shrubs, particularly big sagebrush.

# RESULTS

## Description of Winter Injury

In the areas of sagebrush injury we visited in south-central and southern Idaho and northern Utah, damage occurred primarily above 6,000 ft (1 800 m). This was generally true with survey reports, although in California and Oregon the elevation was somewhat lower. Typically the most severe damage occurred in mountain valleys (cover photo) and other areas of normally deep snow cover (fig. 2). Southwesterly exposures and windswept ridges were usually free of injury. Virtually all large plants of mountain big sagebrush were killed on the high plateau areas we surveyed on Idaho's Sawtooth National Forest and Utah's Uinta and Manti-LaSal National Forests (fig. 3).

**Figure 2.—A depressed area on the lee of a glacial morain with winter-killed mountain big sagebrush. North of Borah Peak, Lost River Range in Idaho.**

**Figure 3.—Extensive sagebrush winter-kill on the high Cassia Plateau of southern Idaho, Sawtooth National Forest.**

Even in the most severe kill areas, however, some young plants up to 12 inches (30 cm) high were not affected (fig. 4). Partial kill of large plants was common (fig. 5), with increased frequency bordering normally exposed areas, protected areas, and areas ascending from valley or canyon bottoms. It was typical for mountain big sagebrush to be killed in canyon bottoms, but not injured at all on adjacent normally exposed or partially exposed slopes. Of the areas we visited, mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) was the only big sagebrush observed to be injured. Basin or valley big sagebrush (*Artemisia tridentata* ssp. *tridentata*) occurs at lower elevations and apparently was not damaged as extensively. This appeared to be generally true from survey reports although familiarity with the subspecies is not universal enough to make this generalization. *Juniperus communis*, a procumbent shrub (fig. 6), was injured virtually everywhere it occurred over the southeastern portion of the Challis National Forest. The foliage on the entire to upper portions of plants had turned brown, but it did not appear that the plants were entirely killed. On the Targhee National Forest in southeastern Idaho, huckleberry (*Vaccinium* spp.), which grows under a canopy of lodgepole pine, was damaged over large areas. Characteristically the upper 6 to 12 inches (15 to 30 cm) of plants were dead and leafless. Snowberry (*Symphoricarpos* spp.) damage on the southern Sawtooth National Forest (fig. 7) in Idaho was similar to that of *Vaccinium*. Spotty to intense winter injury of *Ceanothus* sp. was present almost everywhere the plant occurred (fig. 8).

**Figure 4.—Meadow with winter-killed sagebrush. Note patch of unaffected young sagebrush plants in center of photo, east of Oakley, Idaho, Sawtooth National Forest.**

**Figure 5.—A partially killed mountain big sagebrush on the Sawtooth National Forest, south of Albion, Idaho.**

Figure 6.—Common juniper (arrow), a procumbent shrub, received extensive damage on the Challis National Forest of Idaho.

Figure 7.—Winter-killed snowberry plants on the Sawtooth National Forest, south of Albion, Idaho.

Figure 8.—Typical spotty winter injury of *Ceanothus* near Mt. Harrison, Sawtooth National Forest, Idaho.

Results of the survey of Federal and State land management units are given in tables 1, 2, and 3; and the shrub species damaged are summarized in table 4. Within the survey area, which corresponds generally to the distributional range of big sagebrush, there were large areas with no reported winter injury. These were primarily almost all of Montana and the eastern two-thirds of Wyoming and Colorado. The areas with the most severe winter injury were most of southern Idaho; southwestern Wyoming; northwestern Colorado; northeastern Utah, Nevada, and California; and south-central Oregon. (Refer to tables 1 through 3 for more specific locations.) At least 36 species in 21 genera were reported damaged. *Artemisia tridentata* injury was reported to occur in 190 localities throughout the survey area, followed by *Ceanothus* (118), *Arctostaphylos* (49), and *Purshia* (33). Based on the survey estimate, almost entire kill of sagebrush occurred in locations totaling 340,000 acres (138 000 ha), with spotty kill in 80 additional locations. The actual area of winter kill was undoubtedly much greater. Injury to other species occurred in a much lesser number of locations (table 4). This is probably a reflection of the relative abundance of the various species at least for those at elevations higher than 6,000 ft (1 800 m). We suspect that the lower elevation desert shrubs, *Atriplex, Ceratoides, Grayia, Sarcobatus*, and especially *Coleogyne* were probably killed or injured by drought alone.

**Table 1.**—Winter injury of western wildland shrubs on National Forest lands

| Shrub species | No. of locations[1] of winter injury | Approximate elevation (1,000 ft) | Intensity of injury[2] | Symptoms[3] |
|---|---|---|---|---|
| **CALIFORNIA** | | | | |
| Eldorado | | | | |
| *Arctostaphylos* spp. | 3 | 5.2 | 1 | 1-2 |
| *Ceanothus leucodermis* | 1 | 2.0-3.0 | 2 | 1 |
| *Ceanothus integerrimus* | 3 | 3.2-6.0 | 1-2 | 2-4 |
| Inyo | | | | |
| *Arctostaphylos* spp. | 1 | 7.0-8.5 | 2 | 2-4 |
| *Ceanothus velutinus* | 1 | 7.0-8.5 | 2 | 1-3 |
| Modoc | | | | |
| *Arctostaphylos patula* | 4 | 4.6-7.0 | 2-3 | 1-2 |
| *Artemisia tridentata* | 1 | 5.0 | 2 | 1-3 |
| *Ceanothus velutinus* | 1 | 4.5 | 2-3 | 2-3 |
| *Cercocarpus ledifolius* | 1 | 5.0 | 3 | 1-2 |
| *Juniperus occidentalis* | 1 | -- | 3 | 1,3 |
| *Purshia tridentata* | 1 | 4.2-4.8 | 1-2 | 2 |
| Plumas | | | | |
| *Arctostaphylos* spp. | 1 | 5.0 | 2 | 1,3 |
| *Artemisia tridentata* | 1 | 5.0 | 2 | 2 |
| *Ceanothus cordulatus* | 1 | 5.0 | 2 | 1,3 |
| *Ceanothus cuneatus* | 1 | 5.0 | 2 | 1,3 |
| *Ceanothus velutinus* | 1 | 5.0 | 2 | 2,3 |
| Stanislaus | | | | |
| *Ceanothus cordulatus* | 1 | 6.0 | 2 | 2,3 |
| Tahoe | | | | |
| *Arctostaphylos patula* | 3 | 5.0-7.0 | 2 | 2-3 |
| *Ceanothus cordulatus* | 1 | 6.0-7.0 | 2 | 1-3 |
| *Ceanothus velutinus* | 1 | 4.0-5.5 | 2 | 2-3 |
| *Prunus emarginata* | 1 | 6.9 | 2 | 2 |
| **COLORADO** | | | | |
| Arapaho-Roosevelt | | | | |
| None reported | | | | |
| Gunnison-Grand Mesa Uncomphagre | | | | |
| *Artemisia tridentata* | 1 | 9.4 | 1 | 2,4 |
| *Purshia tridentata* | 1 | 9.0 | 1 | 2,3 |
| Rio Grande | | | | |
| None reported | | | | |
| Routt | | | | |
| *Ceanothus* spp. | 8 | 6.8-11.0 | 1-3 | 2,3 |
| *Juniperus* spp. | 2 | 8.2-11.0 | 2 | 1,3 |
| *Quercus* spp. | 1 | 6.8-7.0 | 2-3 | 2-3 |
| San Juan | | | | |
| None reported | | | | |
| White River | | | | |
| *Quercus gambelii* | 1 | 7.5 | 2 | 2 |
| *Symphoricarpos oreophilus* | 1 | 7.5 | 2 | 2 |

(con.)

Table 1.—(con.)

| Shrub species | No. of locations[1] of winter injury | Approximate elevation (1,000 ft) | Intensity of injury[2] | Symptoms[3] |
|---|---|---|---|---|
| **IDAHO** | | | | |
| Boise | | | | |
| *Artemisia tridentata* | 7 | 5.0-8.0 | 2 | 1 |
| *Ceanothus sanguineus* | 1 | 8.0 | 3 | 2 |
| *Ceanothus velutinus* | 5 | 6.2-7.4 | 1-2 | 3 |
| *Ceanothus* spp. | 1 | 3.0-6.0 | 2 | 3 |
| Caribou | | | | |
| *Artemisia tridentata* | 4 | 6.6-8.0 | 1-2 | 1-2 |
| *Ceanothus velutinus* | 2 | 5.8-8.0 | 1-2 | 1,3 |
| *Ceanothus* spp. | 1 | -- | 2 | 2,3 |
| Challis | | | | |
| *Arctostaphylos* spp. | 2 | 7.0-8.0 | 1-2 | 1-3 |
| *Artemisia tridentata* | 24 | 6.0-7.8 | 1-2 | 1-2 |
| *Ceanothus sanguineus* | 1 | 3.8-8.0 | 1 | 2,3 |
| *Ceanothus* spp. | 1 | 6.0 | 1 | 1,3 |
| *Juniperus communis* | 1 | 7.0 | 1 | 1-3 |
| *Purshia tridentata* | 2 | 6.0-6.5 | 1-2 | 1 |
| *Vaccinium* spp. | 1 | 8.0 | 2 | 2-3 |
| Salmon | | | | |
| *Artemisia tridentata* | 15 | 6.3-8.5 | 1-2 | 1-2 |
| *Ceanothus velutinus* | 4 | 5.8-6.6 | 2 | 2,3 |
| Sawtooth | | | | |
| *Artemisia tridentata* | 12 | 5.5-8.0 | 1-3 | 1,2 |
| *Ceanothus* spp. | 2 | 5.5-8.0 | 1-2 | 2,3 |
| *Purshia tridentata* | 1 | 6.6 | 2 | 1 |
| *Symphoricarpos* spp. | 1 | 6.5 | 2 | 2 |
| Targhee | | | | |
| *Artemisia tridentata* | 3 | 6.5-7.0 | 2 | 1 |
| *Ceanothus* spp. | 5 | 5.0-7.4 | 2-3 | 1-2,3 |
| *Vaccinium* spp. | 1 | 5.0-6.0 | 2 | 2,4 |
| **MONTANA** | | | | |
| Beaverhead | | | | |
| *Artemisia tridentata* | 2 | 6.9-7.8 | 1-2 | 1-2 |
| Custer | | | | |
| None reported | | | | |
| Deerlodge | | | | |
| None reported | | | | |
| Gallatin | | | | |
| *Ceanothus velutinus* | 1 | -- | 2 | 2-3 |
| Lewis and Clark | | | | |
| None reported | | | | |
| **NEVADA** | | | | |
| Humboldt | | | | |
| *Amelanchier* spp. | 1 | 6.0-8.0 | 2 | 1-2 |
| *Artemisia tridentata* | 7 | 8.0-8.4 | 2 | 1,2 |
| *Ceanothus* spp. | 1 | 6.0-8.0 | 2 | 1-2 |
| *Cercocarpus* spp. | 4 | 6.0-8.0 | 1 | 1-2 |
| *Purshia tridentata* | 4 | 6.0-8.0 | 1 | 1-2 |
| *Symphoricarpos* spp. | 4 | 6.0-8.0 | 1 | 1-2 |
| Toiyabe | | | | |
| *Artemisia tridentata* | 9 | 7.0-9.5 | 1-2 | 1-2 |
| *Ceanothus velutinus* | 1 | 6.5-10.0 | 1 | 2 |
| *Ceanothus* spp. | 1 | -- | 1 | 1-3 |

(con.)

Table 1.—(con.)

| Shrub species | No. of locations[1] of winter injury | Approximate elevation (1,000 ft) | Intensity of injury[2] | Symptoms[3] |
|---|---|---|---|---|
| **OREGON** | | | | |
| Deschutes | | | | |
| *Arctostaphylos patula* | 5 | 5.0-7.0 | 2-3 | 1-4 |
| *Ceanothus velutinus* | 2 | 6.0-7.5 | 2-3 | 1-4 |
| *Chrysothamnus nauseosus* | 1 | 4.5 | 2? | 2 |
| *Purshia tridentata* | 1 | 4.7 | 1 | 1 |
| Fremont | | | | |
| *Arctostaphylos* spp. | 4 | 4.5-5.5 | 1 | 1-4 |
| *Artemisia tridentata* | 2 | 5.0-5.5 | 1 | 1-2 |
| *Ceanothus prostratus* | 1 | 5.5 | 1 | 1-3 |
| *Ceanothus velutinus* | 3 | 5.0-7.0 | 1-2 | 1-4 |
| *Purshia tridentata* | 1 | 4.7 | 1 | 1-2 |
| Malheur | | | | |
| *Ceanothus sanguineus* | 4 | 5.5-6.5 | 2 | 1-2 |
| *Ceanothus velutinus* | 1 | 5.0 | 2 | 2 |
| *Salix* spp. | 1 | 5.2 | 2 | 2 |
| Ochoco | | | | |
| *Ceanothus velutinus* | 1 | 4.0-6.5 | 2 | 3 |
| Umatilla | | | | |
| None reported | | | | |
| Wallowa-Whitman | | | | |
| *Ceanothus* spp. | 1 | 5.0-9.0 | 1 | 2 |
| Winema | | | | |
| *Arctostaphylos* spp. | 7 | 4.4-8.0 | 1 | 1 |
| *Ceanothus velutinus* | 7 | 4.4-8.0 | 1 | 1-2 |
| *Purshia tridentata* | 2 | 4.2-7.0 | 1 | 1-2 |
| **UTAH** | | | | |
| Ashley | | | | |
| *Arctostaphylos patula* | 2 | 7.4-8.4 | 1 | 2-3 |
| *Artemisia tridentata* | 3 | 7.0-9.0 | 1-2 | 1-2 |
| *Cercocarpus montanus* | 2 | 6.0-8.2 | 1-2 | 1 |
| *Purshia tridentata* | 1 | 7.0-8.2 | 1-2 | 1 |
| Dixie | | | | |
| *Arctostaphylos* spp. | 3 | 6.9-9.0 | 2 | 1 |
| *Artemisia* spp. | 2 | 7.0-9.0 | 2 | 1 |
| *Purshia tridentata* | 3 | 8.5-9.5 | 1-2 | 1-2 |
| Fishlake | | | | |
| *Amelanchier* spp. | 1 | 7.5 | 1 | 1 |
| *Arctostaphylos* spp. | 6 | 8.5 | 2 | 1,3 |
| *Artemisia tridentata* | 1 | 7.5-9.1 | 1 | 2 |
| *Purshia tridentata* | 2 | 7.5-9.1 | 1-2 | 1-3 |
| Manti-LaSal | | | | |
| *Arctostaphylos* spp. | 1 | 7.0-8.0 | 2 | 1-2 |
| *Artemisia tridentata* | 6 | 7.0-10.0 | 1-2 | 1-2 |
| *Artemisia* spp. | 1 | 9.0-10.0 | 1-2 | 1-2 |
| *Ceanothus* spp. | 3 | 7.5 | 2 | 3 |
| *Juniperus* spp. | 1 | 8.0-9.0 | 3 | 3 |
| Uinta | | | | |
| *Artemisia cana* | 1 | 6.0-8.0 | 2 | 1 |
| *Artemisia tridentata* | 2 | 6.0-8.0 | 1-2 | 1-2 |
| *Ceanothus* spp. | 3 | 7.0-9.0 | 1 | 2 |
| *Chrysothamnus* spp. | 1 | 6.0 | 1 | 2 |
| *Juniperus osteosperma* | 2 | 6.5 | 2 | 3-4 |
| *Pachistima* spp. | 3 | 7.0-9.0 | 2 | 2 |
| *Quercus gambelii* | 3 | 7.0-9.0 | 1 | 2 |
| Wasatch-Cache | | | | |
| *Artemisia tridentata* | 3 | 6.5-9.0 | 1-3 | 2-4 |
| *Ceanothus* spp. | 3 | 6.6-9.0 | 2 | 1,4 |
| **WYOMING** | | | | |
| Bighorn | | | | |
| *Juniperus communis* | 1 | 7.0-9.0 | 2 | 3 |
| Bridger-Teton | | | | |
| *Artemisia tridentata* | 6 | 6.0-9.0 | 1-3 | 1-2 |
| *Ceanothus velutinus* | 2 | 6.5 | 2 | 2-3 |
| *Salix* spp. | 1 | 7.2-10.0 | 2 | 1-2 |
| Medicine Bow | | | | |
| None reported | | | | |
| Shoshone | | | | |
| *Artemisia tridentata* | 2 | 8.0 | 1 | 1-2 |

[1]Locations represent separate areas of shrub winter injury that varied in size from less than an acre to thousands of acres.
[2](1) Areas of from a few to thousands of acres where virtually all plants suffered winter injury, (2) areas of from a few to thousands of acres where winter injury occurred in scattered patches, (3) areas usually small in size where a few plants received winter injury.
[3](1) Entire kill, (2) partial kill, (3) reddish-brown foliage, (4) dead leafless shoots.

Table 2.—Winter injury of western wildland shrubs on Bureau of Land Management lands

| Shrub species | No. of locations[1] of winter injury | Approximate elevation (1,000 ft) | Intensity of injury[2] | Symptoms[3] |
|---|---|---|---|---|
| **CALIFORNIA** | | | | |
| Bishop | | | | |
| None reported | | | | |
| Folsom | | | | |
| None reported | | | | |
| Redding | | | | |
| None reported | | | | |
| Riverside | | | | |
| None reported | | | | |
| Susanville | | | | |
| *Artemisia tridentata* | 1 | 5.8 | 2 | 1 |
| *Juniperus occidentalis* | 1 | 5.2 | 2 | 3 |
| **COLORADO** | | | | |
| Cannon City | | | | |
| None reported | | | | |
| Craig | | | | |
| *Amelanchier alnifolia* | 1 | 7.0-8.0 | 2 | 2 |
| *Artemisia spinescens* | 1 | 6.0 | 2 | 2-4 |
| *Artemisia tridentata* | 3 | 6.6 | 2-3 | 2 |
| *Atriplex confertifolia* | 1 | 6.0 | 2 | 1-4 |
| *Atriplex gardneri* | 1 | 6.0 | 2 | 1-2 |
| *Ceratoides lanata* | 1 | 6.0 | 2 | 2 |
| *Cercocarpus montanus* | 1 | 7.3 | 3 | 2-4 |
| *Juniperus* spp. | 1 | 6.2-6.9 | 3 | 3 |
| *Pinus edulis* | 1 | 6.2-6.9 | 3 | 3 |
| *Purshia tridentata* | 1 | 7.2 | 2 | 4 |
| *Sarcobatus vermiculatus* | 1 | 6.0 | 2 | 4 |
| Grand Junction | | | | |
| *Arctostaphylos patula* | 1 | 7.7 | 3 | 3 |
| *Artemisia tridentata* | 5 | 6.0-8.5 | 1-2 | 1-2 |
| *Quercus gambelii* | 1 | 7.5 | 2 | 4 |
| Montrose | | | | |
| *Artemisia tridentata* | 1 | 6.0-10.0 | 2 | 1,2 |
| *Juniperus communis* | 2 | 9.0-11.0 | 2 | 2-3 |
| *Purshia tridentata* | 1 | 6.5 | 2 | 1-2 |
| *Salix anglorum* | 3 | 7.2 | 2 | 2,4 |
| **IDAHO** | | | | |
| Boise | | | | |
| *Artemisia tridentata* | 3 | 5.8-7.0 | 1-2 | 1-2,4 |
| *Cenothus velutinus* | 3 | 5.0-7.0 | 1-2 | 2-3 |
| *Juniperus* spp. | 1 | 5.8 | 2 | 2 |
| Burley | | | | |
| *Amelanchier alnifolia* | 1 | 5.8 | 1 | 1 |
| *Artemisia tridentata* | 3 | 5.8-6.2 | 1-2 | 1-2 |
| *Ceanothus* spp. | 2 | 6.3-6.4 | 2 | 3 |
| *Chrysothamnus nauseosus* | 2 | 5.8-6.2 | 1 | 1-2 |
| *Purshia tridentata* | 1 | 5.8-6.2 | 1 | 1-2 |
| Idaho Falls | | | | |
| *Artemisia tridentata* | 3 | 4.8-7.5 | 1-2 | 1-4 |
| *Ceanothus velutinus* | 4 | 6.0-7.0 | 1-3 | 1,3 |
| Salmon | | | | |
| *Artemisia tridentata* | 17 | 6.5-8.8 | 1-3 | 1-2,4 |
| *Ceanothus velutinus* | 2 | 6.0-7.5 | 2 | 2 |
| *Purshia tridentata* | 1 | 6.5 | 2 | 1-2 |
| Shoshone | | | | |
| *Artemisia tridentata* | 1 | 5.8 | 2 | 2 |
| *Ceanothus velutinus* | 2 | 5.8-6.8 | 2 | 2 |
| *Prunus virginiana* | 2 | 5.8-6.8 | 2 | 2 |
| **MONTANA** | | | | |
| Butte | | | | |
| *Ceanothus velutinus* | 5 | 5.0-5.4 | 2 | 3 |
| Lewistown | | | | |
| None reported | | | | |
| Miles City | | | | |
| None reported | | | | |

(con.)

Table 2.—(con.)

| Shrub species | No. of locations[1] of winter injury | Approximate elevation (1,000 ft) | Intensity of injury[2] | Symptoms[3] |
|---|---|---|---|---|
| **NEVADA** | | | | |
| Battle Mountain | | | | |
| None reported | | | | |
| Carson City | | | | |
| *Arctostaphylos* spp. | 1 | 6.0 | 1 | 2 |
| Elko | | | | |
| *Artemisia tridentata* | 3 | 6.0-7.5 | 1-2 | 1 |
| *Ceanothus* spp. | 1 | 6.5-7.0 | 1 | 3 |
| *Purshia tridentata* | 4 | 6.0-7.5 | 1-2 | 1-4 |
| Ely | | | | |
| *Arctostaphylos* spp. | 2 | 8.0-9.0 | 2 | 2 |
| *Artemisia tridentata* | 1 | 8.0-8.8 | 2 | 2 |
| Las Vegas | | | | |
| None reported | | | | |
| Winnemucca | | | | |
| *Ceanothus velutinus* | 2 | 6.5-7.8 | 2 | 4 |
| **OREGON** | | | | |
| Baker | | | | |
| None reported | | | | |
| Burns | | | | |
| *Sarcobatus vermiculatus* | 1 | 4.0-4.2 | 1 | 2 |
| Lakeview | | | | |
| *Artemisia tridentata* | 1 | 4.6 | 2 | 1-2 |
| *Juniperus occidentalis* | 1 | 4.5 | 2 | 2-3 |
| Prineville | | | | |
| None reported | | | | |
| Vale | | | | |
| *Purshia tridentata* | 1 | 5.6 | 1 | 2,3 |
| **OREGON-WASHINGTON** | | | | |
| Spokane | | | | |
| None reported | | | | |
| **UTAH** | | | | |
| Cedar City | | | | |
| *Coleogyne ramosissima* | 1 | 3.0 | 1 | 2,4 |
| Moab | | | | |
| None reported | | | | |
| Richfield | | | | |
| *Artemisia tridentata* | 4 | 5.4-8.5 | 2 | 2 |
| *Coleogyne ramosissima* | 1 | 4.4-5.2 | 1 | 2,4 |
| *Ephedra* spp. | 1 | 4.4-5.6 | 1 | 1-4 |
| *Juniperus osteosperma* | 4 | 5.0-7.0 | 2 | 1-3 |
| Salt Lake | | | | |
| *Artemisia tridentata* | 2 | 4.6-6.6 | 2 | 1-2 |
| *Ceanothus velutinus* | 1 | 7.2 | 2 | 2-3 |
| *Juniperus osteosperma* | 1 | 4.6 | 2 | 1 |
| Vernal | | | | |
| *Artemisia nova* | 5 | 5.0-6.0 | 1-2 | 1-2 |
| *Artemisia tridentata* | 8 | 5.0-6.0 | 1-2 | 1-2,4 |
| *Atriplex confertifolia* | 5 | 5.0-6.0 | 2 | 2,4 |
| *Juniperus osteosperma* | 3 | 5.6-6.5 | 1 | 1-3 |
| **WYOMING** | | | | |
| Casper | | | | |
| None reported | | | | |
| Rawlins | | | | |
| None reported | | | | |
| Rock Springs | | | | |
| *Arctostaphylos* spp. | 2 | 7.0-8.0 | 1 | 2-3 |
| *Artemisia cana* | 1 | 6.5-7.0 | 2 | 2,4 |
| *Artemisia tridentata* | 4 | 6.0-8.0 | 1-2 | 1-2 |
| *Atriplex confertifolia* | 1 | 6.1 | 1 | 1 |
| *Ceanothus* spp. | 1 | 7.5-8.5 | 1 | 2 |
| *Chrysothamnus* spp. | 1 | 6.1 | 1 | 1 |
| *Grayia spinosa* | 1 | 6.1 | 1 | 1 |
| *Sarcobatus vermiculatus* | 1 | 6.1 | 1 | 1 |
| Worland | | | | |
| *Atriplex nuttallii* | 1 | 4.5 | 2 | 2 |
| **NORTH DAKOTA** | | | | |
| Dickinson Wyo. | | | | |
| None reported | | | | |

[1]Locations represent separate areas of shrub winter injury that varied in size from less than an acre to thousands of acres.
[2](1) Areas of from a few to thousands of acres where virtually all plants suffered winter injury, (2) areas of from a few to thousands of acres where winter injury occurred in scattered patches, (3) areas usually small in size where a few plants received winter injury.
[3](1) Entire kill, (2) partial kill, (3) reddish-brown foliage, (4) dead leafless shoots.

**Table 3.**—Winter injury of western wildland shrubs reported by State Divisions of Wildlife Resources

| Shrub species | No. of locations[1] of winter injury | Approximate elevation (1,000 ft) | Intensity of injury[2] | Symptoms[3] |
|---|---|---|---|---|
| **COLORADO** | | | | |
| Southwest | | | | |
| *Artemisia tridentata* | 1 | 8.5 | 2 | 2 |
| *Purshia tridentata* | 1 | 8.0 | 1 | 2 |
| Northwest | | | | |
| None reported | | | | |
| **IDAHO** | | | | |
| Region 1 | | | | |
| *Ceanothus* spp. | -- | -- | -- | -- |
| Region 2 | | | | |
| None reported | | | | |
| Region 3 | | | | |
| *Artemisia tridentata* | 2 | 5.6 | 1 | 1 |
| *Ceanothus* spp. | 4 | 4.0-6.0 | 2 | 1-3 |
| Region 4 | | | | |
| *Artemisia tridentata* | 2 | 5.0-7.0 | 1 | 1 |
| Region 6 | | | | |
| *Artemisia tridentata* | 4 | 6.0-8.0 | 1 | 1-2 |
| *Ceanothus* spp. | 2 | 6.0-7.0 | 1 | 2-3 |
| **NEVADA** | | | | |
| Region II | | | | |
| *Artemisia tridentata* | 2 | 6.5-7.0 | 1-2 | 1-2 |
| *Ceanothus* spp. | 1 | 6.8-8.0 | 2 | 3 |
| *Purshia tridentata* | 5 | 6.5-8.0 | 1-2 | 1-2,4 |
| **OREGON** | | | | |
| Southeast Region | | | | |
| *Ceanothus prostratus* | 4 | -- | 2 | 1-4 |
| *Symphoricarpos* spp. | 4 | -- | 2 | 1-4 |
| **UTAH** | | | | |
| Southern Region | | | | |
| *Artemisia tridentata* | 3 | -- | 1 | 1 |
| *Pinus edulis* | 1 | -- | 3 | 1 |
| Southeastern Region | | | | |
| *Artemisia tridentata* | 2 | -- | 1 | 1-2 |
| Northern Regions | | | | |
| *Ceanothus velutinus* | 6 | 6.0-9.0 | 2 | 2,3 |
| **WYOMING** | | | | |
| Southwest | | | | |
| *Artemisia cana* | 1 | 6.0-9.0 | 1 | 1-2 |
| *Artemisia tridentata* | 3 | 6.5-9.0 | 1 | 1-2 |
| *Ceanothus velutinus* | 3 | 7.0-8.5 | 1 | 2-3 |
| *Juniperus communis* | 2 | 8.0-9.0 | -- | -- |
| *Vaccinium* spp. | 2 | 8.0-9.0 | 1-2 | 1-3 |
| Southeast | | | | |
| None reported | | | | |

[1]Locations represent separate areas of shrub winter injury that varied in size from less than an acre to thousands of acres.
[2](1) Areas of from a few to thousands of acres where virtually all plants suffered winter injury, (2) areas of from a few to thousands of acres where winter injury occurred in scattered patches, (3) areas usually small in size where a few plants received winter injury.
[3](1) Entire kill, (2) partial kill, (3) reddish-brown foliage, (4) dead leafless shoots.

Table 4.—List of shrub species reported with winter injury or drought damage

| Shrub species | No. of locations observed | Shrub species | No. of locations observed |
|---|---|---|---|
| *Amelanchier alnifolia* (Nutt.) Nutt. | 2 | *Coleogyne ramosissima* Torr. | 2 |
| *Amelanchier* Medic. spp. | 2 | | |
| *Arctostaphylos patula* Greene | 17 | Ephedra L. sp. | 1 |
| *Arctostaphylos* Adans. spp. | 32 | | |
| | | *Grayia spinosa* (Hook.) Moq. | 1 |
| *Artemisia cana* Pursh | 3 | | |
| *Artemisia nova* (A. Nels.) Ward | 5 | *Juniperus communis* L. | 6 |
| *Artemisia spinescens* D.C. Eaton | 1 | *Juniperus occidentalis* Hook. | 3 |
| *Artemisia tridentata* Nutt. | 190 | *Juniperus osteosperma* Torr. Little | 11 |
| *Artemisia* L. spp. | 4 | *Juniperus* L. spp. | 5 |
| *Atriplex confertifolia* (Torr. & Frem.) S. Wats. | 7 | *Pachistima* Raf. sp. | 3 |
| *Atriplex gardneri* (Moq.) D. Dietr. | 1 | *Pinus edulis* Engelm. | 2 |
| *Atriplex nuttallii* S. Wats. | 1 | *Prunus emarginata* (Dougl.) Walp. | 1 |
| *Ceanothus cordulatus* Kellogg | 3 | *Prunus virginiana* L. | 2 |
| *Ceanothus cuneatus* (Hook.) Nutt. | 1 | | |
| *Ceanothus integerrimus* Hook. & Arn. | 3 | *Purshia tridentata* (Pursh) DC | 33 |
| | | *Quercus gambelii* Nutt. | 5 |
| *Ceanothus leucodermis* Greene | 1 | *Quercus* L. spp. | 1 |
| *Ceanothus prostratus* Benth. | 5 | | |
| *Ceanothus sanguineus* Pursh | 6 | *Salix anglorum* Schenid. | 1 |
| *Ceanothus velutinus* Dougl. | 55 | *Salix* L. spp. | 2 |
| *Ceanothus* L. spp. | 44 | | |
| *Ceratoides lanata* (Pursh) J. T. Howell | 1 | *Sarcobatus vermiculatus* (Hook.) Torr. | 3 |
| *Cercocarpus ledifolius* Nutt. | 1 | *Symphoricarpos oreophilus* A. Gray | 1 |
| *Cercocarpus montanus* Raf. | 3 | | |
| *Cercocarpus* HBK. spp. | 1 | *Symphoricarpos* Duhamel. spp. | 9 |
| *Chrysothamnus nauseosus* (Pall.) Britton | 3 | *Vaccinium* L. spp. | 4 |
| *Chrysothamnus* Nutt. spp. | 2 | | |

## Correlation with Weather Records

Of the eight Western States included in the study, Oregon, Idaho, California, and Utah had the lowest monthly accumulated percentage of normal precipitation (table 5). Montana and Wyoming were the highest, with Nevada and Colorado intermediate. This agrees roughly with the reported extent of winter injured shrubs. December had the lowest monthly accumulated percentage of normal, with January, November, and February slightly higher. Normally, these are months of higher precipitation and snow cover. A comparison of precipitation in climatic divisions corresponding to areas of high winter injury and low winter injury indicates that the average divisional precipitation was from about 20 to 45 percent lower in areas of high winter injury (tables 6 and 7 and fig. 9). The largest percentage difference was during December through April. The average actual monthly accumulated precipitation was nearly the same in the respective areas.

Table 5.—Monthly accumulated precipitation for October through April, 1976-77[1]

| State | Precipitation[2] | | | | | | |
|---|---|---|---|---|---|---|---|
| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. |
| California | 0.45 | 1.11 | 1.47 | 3.12 | 4.35 | 5.58 | 5.75 |
| | 53 | 33 | 23 | 34 | 34 | 36 | 34 |
| Colorado | 0.56 | 0.81 | 0.96 | 1.25 | 1.82 | 2.46 | 3.93 |
| | 48 | 43 | 37 | 41 | 44 | 47 | 60 |
| Idaho | 0.56 | 0.74 | 0.93 | 1.53 | 1.91 | 1.78 | 2.92 |
| | 62 | 32 | 23 | 29 | 29 | 35 | 33 |
| Montana | 0.60 | 1.01 | 1.31 | 2.07 | 2.33 | 3.35 | 3.68 |
| | 70 | 68 | 65 | 81 | 76 | 86 | 72 |
| Nevada | 0.79 | 0.96 | 0.99 | 1.55 | 1.87 | 2.34 | 2.51 |
| | 135 | 70 | 45 | 50 | 46 | 49 | 44 |
| Oregon | 0.80 | 1.58 | 2.22 | 3.07 | 4.34 | 6.89 | 7.44 |
| | 29 | 24 | 19 | 22 | 25 | 32 | 31 |
| Utah | 0.76 | 0.83 | 0.87 | 0.98 | 1.82 | 2.52 | 2.80 |
| | 70 | 42 | 28 | 34 | 35 | 38 | 37 |
| Wyoming | 0.66 | 1.04 | 1.29 | 1.89 | 2.21 | 3.41 | 4.43 |
| | 73 | 66 | 59 | 67 | 65 | 78 | 75 |

[1]Average precipitation of the climatic divisions within the distributional zone of *Artemisia tridentata*.

[2]Upper figure represents the actual precipitation in inches. Lower figure represents the percent of normal based on the 1941-70 record.

**Table 6.**—Areas of most intense shrub winter injury and average precipitation of corresponding climatic divisions

| Area | Climatic division | Percent monthly precipitation[1] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. |
| **CALIFORNIA** | | | | | | | | |
| Eldorado N.F.<br>Tahoe N.F.<br>Plumas N.F. | Sacramento drainage | 14 | 22 | 15 | 22 | 26 | 29 | 28 |
| Modoc N.F.<br>Susanville (BLM) | Northeast interior basin | 40 | 23 | 13 | 20 | 28 | 30 | 29 |
| **COLORADO** | | | | | | | | |
| Routt N.F.<br>Craig (BLM)<br>Grand Jct. (BLM)<br>Montrose (BLM) | Colorado drainage | 23 | 23 | 19 | 28 | 31 | 34 | 39 |
| **IDAHO** | | | | | | | | |
| Salmon N.F.<br>Challis N.F.<br>Salmon (BLM) | Northeast valleys | 34 | 26 | 21 | 30 | 26 | 37 | 34 |
| Boise N.F. | Central mountains | 29 | 24 | 23 | 24 | 25 | 34 | 32 |
| Boise (BLM) | Southwest valleys | 28 | 16 | 13 | 20 | 22 | 28 | 27 |
| Boise (BLM) | Southwest highlands | 84 | 49 | 31 | 28 | 31 | 31 | 32 |
| South Sawtooth N.F.<br>Caribou N.F.<br>Burley (BLM) | Eastern highlands | 72 | 34 | 27 | 35 | 35 | 39 | 38 |
| Shoshone (BLM) | Central plains | 81 | 32 | 19 | 23 | 25 | 27 | 25 |
| **NEVADA** | | | | | | | | |
| Humboldt N.F.<br>Elko (BLM) | Northeastern | 103 | 57 | 35 | 40 | 39 | 45 | 42 |
| Toiyabe N.F. | South-central | 248 | 126 | 81 | 79 | 63 | 63 | 55 |
| **OREGON** | | | | | | | | |
| Fremont N.F.<br>Winema N.F.<br>Lakeview (BLM) | High plateau | 31 | 18 | 13 | 14 | 18 | 24 | 24 |
| Winema N.F.<br>Lakeview (BLM)<br>Malheur N.F.<br>Ochoco N.F.<br>Deschutes N.F.<br>Prineville (BLM) | South-central | 26 | 21 | 15 | 20 | 23 | 25 | 24 |
| **WYOMING** | | | | | | | | |
| Bridger N.F.<br>Teton N.F. | Snake drainage | 49 | 39 | 32 | 39 | 35 | 40 | 38 |
| Rock Springs (BLM) | Green and Bear drainage | 14 | 11 | 11 | 18 | 18 | 30 | 31 |
| **UTAH** | | | | | | | | |
| Uinta N.F.<br>Ashley N.F. | Northern mountains | 36 | 18 | 12 | 17 | 28 | 35 | 33 |
| Vernal (BLM) | Uinta Basin | 16 | 10 | 7 | 18 | 26 | 28 | 36 |
| Fishlake N.F.<br>North Manti-Lasal N.F.<br>Richfield (BLM) | South-central | 71 | 51 | 34 | 38 | 36 | 41 | 36 |

[1]Average percent of accumulated normal based on 1941-70.

Table 7.—Areas of little or no reported winter injury and precipitation of corresponding climatic divisions

| Area | Climatic division | Percent monthly precipitation[1] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. |
| **COLORADO** | | | | | | | | |
| Arapaho N.F. Roosevelt N.F. | Platte drainage | 83 | 62 | 59 | 53 | 54 | 65 | 89 |
| Rio Grande N.F. | Rio Grande drainage | 39 | 45 | 33 | 41 | 47 | 42 | 52 |
| **MONTANA** | | | | | | | | |
| Custer N.F. | Southeastern | 107 | 94 | 87 | 108 | 100 | 121 | 92 |
| Gallatin N.F. | South-central | 108 | 90 | 77 | 90 | 82 | 97 | 80 |
| Deer Lodge N.F. Lewis and Clark N.F. | Central | 51 | 67 | 60 | 73 | 77 | 81 | 70 |
| **OREGON** | | | | | | | | |
| Umatilla N.F. Wallowa-Whitman N.F. | North-central | 25 | 24 | 21 | 20 | 24 | 30 | 28 |
| Baker (BLM) | Northeast | 30 | 28 | 23 | 25 | 28 | 36 | 35 |
| **WYOMING** | | | | | | | | |
| Bighorn N.F. | Bighorn | 113 | 83 | 73 | 81 | 78 | 70 | 71 |
| Worland (BLM) | Powder Little Missouri, and Tongue drainage | 132 | 116 | 100 | 111 | 115 | 131 | 110 |
| Casper (BLM) | Belle Fourche drainage | 71 | 104 | 93 | 112 | 114 | 130 | 107 |
| | Cheyenne and Niobrara drainage | 68 | 94 | 86 | 92 | 81 | 100 | 103 |
| Medicine Bow N.F. | Upper Platte drainage | 57 | 40 | 40 | 47 | 48 | 65 | 74 |
| Rawlins (BLM) | Lower Platte drainage | 64 | 56 | 51 | 55 | 52 | 64 | 84 |
| | Wind River | 97 | 70 | 63 | 68 | 67 | 104 | 93 |

[1]Average percent of accumulated normal based on 1941-70 normal.

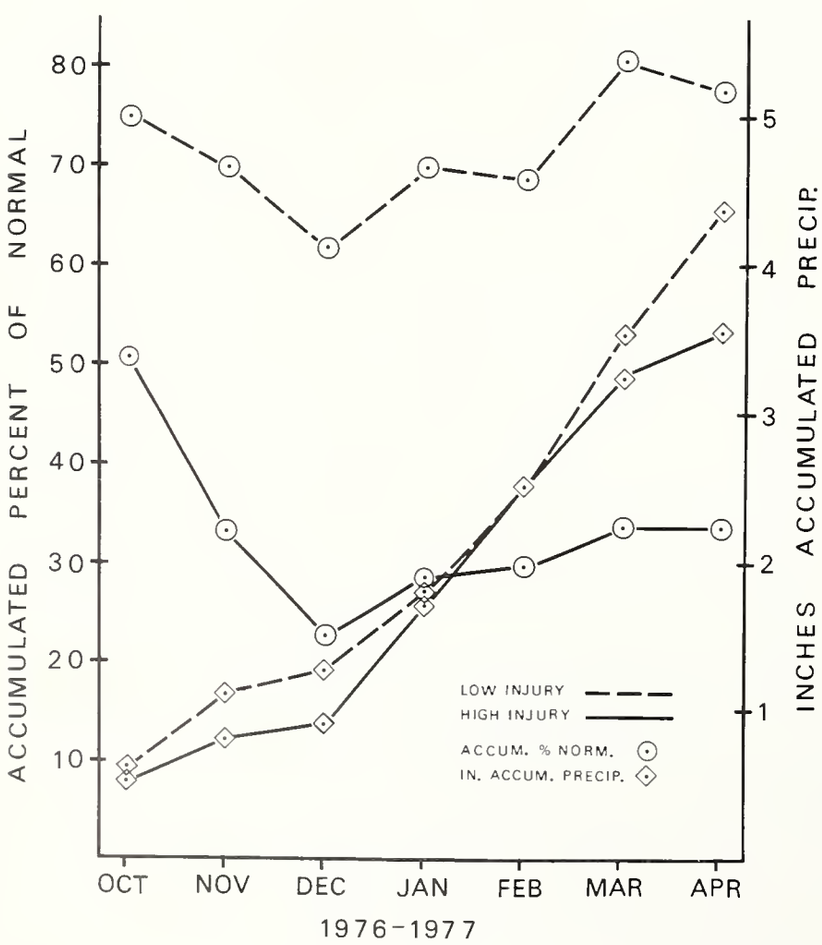


**Figure 9.—Comparison of precipitation in areas of low and high amounts of winter injury.**

Table 8.—Monthly temperature data for October through April, 1976–77[1]

| State | Monthly mean temperature[2] | | | | | | |
|---|---|---|---|---|---|---|---|
| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. |
| | °F | | | | | | |
| California | 59.1 | 50.9 | 41.3 | 37.5 | 38.6 | 43.8 | 56.6 |
| | 0.5 | 0.5 | 0.3 | −1.9 | −4.5 | −2.9 | 3.4 |
| Colorado | 42.0 | 32.3 | 23.4 | 18.9 | 28.2 | 30.9 | 44.1 |
| | −4.1 | −0.7 | −0.9 | −2.7 | 0.2 | −0.5 | 2.2 |
| Idaho | 45.4 | 36.4 | 26.3 | 19.1 | 30.0 | 33.3 | 48.4 |
| | −1.9 | 1.8 | 0.3 | −3.5 | 1.8 | −0.6 | 4.4 |
| Montana | 43.6 | 31.6 | 26.2 | 13.5 | 32.3 | 32.9 | 47.4 |
| | 2.4 | 0 | 3.8 | −3.7 | 9.5 | 4.1 | 5.2 |
| Nevada | 48.9 | 41.2 | 30.6 | 27.3 | 36.6 | 34.0 | 49.2 |
| | −1.4 | 2.8 | −0.3 | −1.5 | 2.9 | −3.3 | 3.1 |
| Oregon | 48.7 | 41.0 | 31.7 | 25.5 | 37.0 | 37.0 | 48.7 |
| | 0.3 | 2.9 | −0.3 | −3.5 | 1.3 | −1.3 | 3.6 |
| Utah | 49.0 | 39.7 | 29.0 | 25.8 | 34.5 | 36.1 | 52.2 |
| | −2.7 | 1.5 | −0.1 | −0.3 | 2.8 | −2.2 | 3.3 |
| Wyoming | 42.0 | 31.4 | 24.2 | 16.1 | 28.1 | 29.5 | 44.7 |
| | 0.8 | 0 | 1.3 | −3.5 | 4.1 | 0.4 | 3.7 |

[1]Average mean temperature of the climatic divisions within the distributional zone of *Artemisia tridentata*.
[2]Upper figure represents the actual monthly mean temperature, °F. Lower figure represents the departure from normal based on the 1941–70 record.

The monthly mean temperature departure from normal varied little between States (table 8). For most States, October was below normal, November above, December and January below, February above, March below, and April above.

## DISCUSSION AND CONCLUSIONS

As far as we have been able to determine, the winter injury of wildland shrubs reported here is the most extensive winter injury of indigenous plants ever recorded in the United States. The extensive kill of big sagebrush over large areas represents a significant natural vegetational change. These areas will eventually return to sagebrush, however, because some young plants survived and seeding will occur from plants in surrounding areas. Although *Ceanothus* and *Arctostaphylos* commonly receive winter injury, it is seldom reported. This is the first report of winter injury to most of the other shrub species listed here.

It is beyond our objective to establish the precise cause of the reported winter injury by an analysis of past weather records. Averaged weather data tend to mask extremes that likely affect plant development and cause injury most directly. Because of the high elevation, distributional pattern of the various shrubs, and remoteness of the sites involved, few weather stations exist that keep complete long-term records for the precise areas where winter injury occurred.

The weather conditions during the winter of 1976–77 caused winter injury that could have resulted from either freezing or winter desiccation or both. The extremely low precipitation during November through February and resulting low snow cover very likely resulted in frozen soil in those areas where it is normally frozen slightly or not at all. In addition, soil moisture levels were unusually low. The lack of snow and generally above normal temperatures in November could have delayed dormancy formation in shrubs. This, followed by continued lack of snow cover and generally below normal temperatures in December, could have resulted in freezing injury. February was above normal in temperature, which could have stimulated growth activity in plants that had broken winter dormancy. During this time, consequential increased transpiration with soils of low available moisture, either due to frozen soil or lack of moisture, could have resulted in desiccation of upper plant parts. Below normal March temperatures followed, and this could also have resulted in freezing injury to plants that were possibly stimulated to growth activity during February. For the most part these conclusions support those of Schumaker and others (1979) and Hanson and others (1982).

Although the monthly accumulated percent of normal precipitation in areas of little or no winter injury was around 20 to 45 percent higher than in areas of extensive winter injury, the actual accumulated precipitation was nearly the same. This could indicate that snow cover was actually no greater and plant water deficits were probably just as high as in areas of winter injury. If this is true, it would seem to suggest that an underlying factor leading to winter injury of some of these shrubs, in addition to high water deficits and lack of snow cover, could be less selection for winter hardiness. For example, sagebrush in protected areas of usual snow cover and of the same subspecies as on an adjacent exposed site, may not be selected for winter hardiness to the same extent as their counterpart on the exposed site. This of course assumes other factors are equal. Frost penetration during inversions, for example, is likely greater in valley bottoms when there is little or no snow cover than on adjacent exposed slopes. Shrubs such as *Ceanothus velutinus* and *Arctostaphylos patula*, which are commonly damaged by winter injury, sprout from lower stems and the root crown and thereby survive without the need for extreme winter hardiness.

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Extensive winter injury of native wildland shrubs occurred in the Western United States during the winter of 1976-77. *Artemisia tridentata* was damaged most extensively followed by *Ceanothus* spp., *Arctostaphylos* spp., *Purshia* spp., and 32 other species of shrubs. The record low precipitation during this period, and consequential low snow cover in areas of normally heavy snow cover, combined with other factors that led to the injury.

KEYWORDS: Western U.S.A. shrub species, winter injury, winter desiccation, winter kill, winter freezing, drought damage

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